APPENDIX B: DATA ACQUISITION (DA) SOFTWARE

B. 1 Introduction

The RSMS is designed to identify and characterize usage at certain frequencies or in selected bands, and to perform in-depth analysis of factors such as system compatibilities with each other or with spectrum assignments. Because of the diverse signal types encountered when measuring an extended spectrum, the measurement system must be able to detect all or at least most of the signals and to display or record as much information about them as possible. Obviously, a general purpose measurement system cannot receive every signal type; however, the RSMS receiver detects almost every signal type encountered. As shown in Appendix A, the RSMS hardware can be configured as a receiver for practically all signal types occurring within an extended frequency range spanning 100 Hz to 19.7 GHz.

The key to efficient use of this extended measurement capability is rapid reconfiguration. The RSMS uses software developed by ITS to control all measurement system functions via computer. This control program, called “DA” (for Data Acquisition), runs on any DOS-based computer with sufficient memory. It interfaces via general-purpose interface bus (GPIB) with the measurement system at rates limited only by the computer’s operating speed and functional speed of the managed hardware (interfaces, switches, components, etc.). DA will support any available combination of RF front-ends, spectrum analyzers, and auxiliary analysis equipment. DA also controls noise diode calibration of the RSMS and characterizes the noise figure and gain for individual components and entire measurement signal paths.

The DA program is basically four control subroutines that direct operation of multiple subroutine kernels that in turn control every function of the measurement system. This appendix includes descriptions of the four control subroutines (receiver algorithm, spectrum analyzer, RF front-end, and calibration) and the resultant system functions. As DA program development continues to meet new measurement demands, these functional descriptions may change with time.

B.2 Receiver Algorithm Subroutine

The DA receiver algorithm subroutine provides software management for up to 32 measurement algorithms (called program kernels in DA or band events for RSMS operations, see Section 2.3. 1). Any one of these algorithms, when coupled with spectrum analyzer and front-end selections (described later in this appendix), becomes a customized measurement system for receiving certain signals or signal types. Because the characteristics of emitters and the requirements for data on those emitters vary considerably, many different algorithms have been developed. However, all of the algorithms are based upon either a frequency sweep across the spectrum of interest, or a series of discrete steps across that spectrum.

For spectrum surveys, sweeping algorithms are generally used to examine spectral bands occupied by high duty cycle emitters such as mobile radios and television transmitters, and stepping algorithms are used to monitor spectral bands occupied by low duty cycle emitters such as radiolocation equipments (radars). Following are brief descriptions of the algorithms used during the Denver survey.

Swept: This algorithm controls a conventional spectrum analyzer[1] sweep across a selected portion of spectrum. Any type of detection available in the analyzer (i.e., positive peak, sample, etc.) can be used. Repeated sweeps may be programmed, and multiple sweeps incorporating the maximum-hold spectrum analyzer mode may also be performed. This algorithm also allows for sweeping a spectral band in several sub-bands (scans). This feature is important if a narrow bandwidth (e.g., 10 kHz) must be used to measure a spectral band that is more than 1000 times the width of the measurement bandwidth, e.g., measuring 900-930 MHz with a 10-kHz bandwidth requires at least three scans to ensure no loss of data.

Swept/m3: This is a swept measurement (as described above) that produces three data traces across a measurement range. At each of the 1000. frequencies measured on each individual spectrum analyzer sweep, the maximum, minimum, and (linear) mean received signal levels are measured. Repeated sweeps are made across the spectrum of interest, and for each of the measurement points returned from each sweep, the three registers for current maximum, minimum and mean are updated. This process continues until it is halted programmatically. The total amount of time for each sweep, and the total number of sweeps to be performed, are specified in advance by the operator. The duration of each individual sweep may be a few milliseconds, with a typical Swept/m3 measurement (hundreds of sweeps) lasting a total of several minutes. These cumulative three-trace Swept/m3 measurements are saved on magnetic media, and may themselves be cumed (see Section 3.3) in the analysis, phase of a site survey to yield long-term Swept/m3 curves. Typical RSMS site surveys use Swept/m3 measurements for mobile radio bands.

Stepped: Stepping measurements consist of a series of individual amplitude measurements made at predetermined (fixed-tuned) frequencies across a spectrum band of interest. The measurement system remains tuned to each frequency for a specified measurement interval. This interval is called step-time, or dwell. The frequency interval for each step is specified by an operator, and is usually about equal to the IF bandwidth of the measurement system. For example, measurements across 200 MHz might use 200 steps at a 1-MHz step interval and a 1-MHz IF bandwidth. Computer control of the measurement system is needed for this (step, tune, and measure) process to be performed at maximum speed.

Stepped measurements are usually performed to capture peak signals occurring on an intermittent basis. A prime example is a periodically scanning radar. If the step-time (dwell) is set slightly longer than the interval between visitations of the radar beam, then the maximum receivable level from the beam will illuminate the RSMS at some time during that interval. The RSMS, which is fixed-tuned for the entire dwell period, records each peak-detected point during that interval and the maximum amplitude recorded is saved for that frequency. The RSMS then tunes to the next frequency (one step), and repeats the process until the entire specified spectrum has been measured.

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[1] For spectrum surveys and most RSMS operations with DA software control, any GPIB interfaced spectrum analyzer that processes at least 1000 points (frequencies) per display sweep may be used.

For intermittently received signals, such as scanned-beam radars, the stepped algorithm has advantages over swept measurements. Stepping is faster, allows more dynamic range (attenuation can be added and subtracted as a function of measured frequency to extend the total available dynamic range of the measurement system), and has better repeatability than swept measurements.

The RSMS uses stepped measurements to gather data in radiolocation bands where measurements can be tailored to transmitter characteristics; i.e., dwell times, IF bandwidths, step widths, etc. are determined as a function of the parameters of the radiolocation equipments which normally operate in the band.

Swept/az-scan: This is not currently a selectable algorithm in DA, but is a hybrid routine using the Swept algorithm (above) with a rotating dish antenna. The dish is targeted on the horizon then rotated 360° while the Swept algorithm is running with positive peak detection and Maximum-Hold screen mode on the spectrum analyzer. The result is an analyzer display that shows the maximum activity across a band in an omnidirectional receiver sense, but with the effective gain of a dish antenna. This routine is most useful for nondynamic bands where received signal levels tend to be weak. Good examples are the common carrier (point-to-point) microwave bands; their transmitters are fixed-tuned, operate continuously, and do not move. The transmitters are also low-powered, and use high-gain antennas which further reduce their probability of intercept.

B.2.1 Receiver Parameters

Following are brief descriptions of the DA program input parameters needed to run the above subroutines (algorithms). Brackets identify the corresponding column headings as they appear in the band event tables of Section 2.3.1. For example, [algor] in the tables shows which of the above described subroutines (algorithms) is controlling the band event.

Start and Stop Frequencies [start (MHz)] [end (MHz)]: The value in MHz of the first and last frequency point to be measured. These numbers must be equal to or fall outside the event frequency band range.

Passes: The number of times the algorithm iterates for each run command. This value is always one for spectrum surveys.

Scans [scns #of]: The number of measurement sub-bands to occur between the start and stop frequencies. This value is usually determined by comparing measurement bandwidth and frequency range. For example, a 30-MHz frequency range measured with a 100-kHz IF bandwidth would ensure sampling of all frequencies (1001 points) in one scan. However, if a 10-kHz IF bandwidth were used in the above example, three scans would be required to ensure sampling of all frequencies.

The Sweeps [swps#of]: The number of sweeps in each scan. DA processes each sweep so increasing this number can add greatly to measurement time; however, increasing this value also increases the probability of intercept for intermittent signals.

Steps [steps #of]: The number of frequency steps to occur between the start and stop frequencies. This parameter is only used with stepped algorithms.

Graph Min and Graph Max: The minimum and maximum values in dBm for the graphical display of measured amplitude data.

B.3 Spectrum Analyzer Subroutine

The DA spectrum analyzer subroutine manages configuration control strings (via GPIB) for the spectrum analyzer. The operator selects spectrum analyzer parameters (listed in the following subsection) from menus in the DA program. Generally, parameters are selected that will configure the analyzer to run with a receiver algorithm for a desired measurement scenario. DA protects against out-of-range and nonlinear configurations but the operator can control the analyzer manually for unusual situations.

B.3.1 Spectrum Analyzer Parameters

When the DA program sends command strings to the analyzer, all signal path parameters are reset according to the operator selections for the measurement scenario. Following are brief descriptions of the analyzer parameter choices controlled by DA. Brackets identify the corresponding column headings as they appear in the band event tables of Section 2.3.1.

Attenuation: May be adjusted from 0-70 dB in 10-dB increments. The spectrum analyzer subroutine determines whether or not RSMS front-end attenuators are available and if so will set them to the selected value. Spectrum analyzer attenuation is set to zero when RSMS attenuation is active, if however, RSMS attenuators are not available the spectrum analyzer attenuation will be set to the selected value.

IF Bandwidth [IFBW (kHz)]: May be selected from 0.01-3000 kHz in a 1, 3, 10 progression.

Detector [detecl: Normal, positive peak, negative peak, sample, maximum hold, and video average modes are available. See Appendix C for discussions on detector selection for receiver algorithms.

Video Bandwidth [VBW (kHz)]: May be selected from 0.01-3000 kHz in a 1, 3, 10 progression.

Display: Amplitude graticule choices in dB/division are: 1, 2, 5, and 10. This parameter selection applies to both the analyzer and the system console displays.

Reference Level [RL (dBm)]: May be adjusted from -10 to -70 dBm in 10-dB increments.

Sweeps [mh/va #swpsl: Number of analyzer processed sweeps per scan. This parameter is only used with maximum hold or video averaged detection.

Sweep Time [swp/stp tm(sec)]: This parameter (entered in seconds) specifies sweep (trace) time if used with swept algorithms, or specifies step-time (dwell) if used with a stepped algorithm.

B.4 RF Front-end Subroutine

The DA software handles the RF front-end path selection differently than other routines. Most of the RF-path parameters are predetermined by the measurement algorithm so operators need only select an antenna and choose whether preamplifiers are turned on or off. preselection is also controlled by the antenna selection.

The antenna selection is made from a list of antenna choices that is stored in a separately maintained library file called by the RF Front-end Subroutine. Antenna information stored in the file includes:

- antenna type (omni, cavity-backed, etc.);
- manufacturer (may include identification or model number);
- port (tells the computer where signals enter the RSMS and includes particulars on any external signal conditioning such as special mounting, additional amplifiers, or extra path gain or loss);
- frequency range;
- vertical and horizontal beam widths;
- dB gain;
- front to back ratio; and
- side lobe levels.

B.5 Calibration Subroutine

The calibration subroutine may be run at any time the operator chooses, but measurements must be interrupted. The software is interactive and flexible, allowing the operator to. choose any calibration path desired. RSMS calibrations are performed with noise diodes and Y-factor excess noise ratio (ENR) techniques. Typically, an entire signal path is calibrated with a noise diode ENR source; a noise diode-is connected at the point where the RF line attaches to the receiver antenna. The connection may be accomplished manually or via an automatic relay, depending upon the measurement scenario. The noise level in the system is measured across the desired frequency range with the noise diode turned on (diode on) and turned off (diode off). The measured difference between the conditions of diode on vs. diode off is compared to the known ENR of the diode (typically +25 dB for RSMS diodes). From these measured values, noise figure and gain calibration curves for the entire signal path are stored in the computer. These frequency-dependent curves are used to automatically correct the measured amplitudes of all received signals in subsequent measurements. This calibration

technique has proven very successful for field-deployed systems. It is a fast way to determine sensitivity and gain correction values for a measurement system, and it is also very useful for isolating the gains and losses through individual components of the measurement system, such as RF lines and amplifiers.